ETHNOBIOLOGY AND CONSERVATION

RESEARCH ARTICLE

Ethnobiology and Conservation, 12:15 (22 July 2023)
doi:10.15451/ec2023-07-12.15-1-35
ISSN 2238-4782 ethnobioconservation.com

Wild food plants with the potential to improve food and nutrition security may be threatened by timber extraction: A systematic review of the Brazilian context

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ABSTRACT

Wild food plants can contribute to improving the food and nutrition security of local populations by promoting diet diversification and increasing the intake of micro- and macronutrients. However, many of these plants are also used as timber. Wild food species need to be identified and their food–wood use interactions need to be well understood for the development of conservation strategies, as species with the potential to improve food and nutrition security may be threatened by destructive extraction. This systematic review recorded and compiled nutritional information on woody plant species native to Brazil that are used by local populations for food and timber purposes, seeking to identify which species have a high overlap between food and timber uses as well as a high nutritional potential. A total of 635 woody species with timber and/or food uses were identified. Of this total, at least 42 species find application in all timber use categories analyzed in this study, being considered versatile. Comparison of ethnobiological and nutritional data revealed nine versatile species for which nutritional composition information was available, among which three stood out in terms of macronutrient contents, namely *Anacardium occidentale* L., *Bauhinia cheilantha* (Bong.) Steud., and *Eugenia pyriformis* Cambess. Many versatile species classified as threatened or in decline have not been the focus of nutritional studies, which signals the need for greater nutritional research efforts. It is also necessary to investigate whether food importance exerts any protective effect on these species, reducing timber use pressure (protection hypothesis).

Keywords: Biocultural conservation, Ethnobotany, Food use, Nutritional composition, Timber use, Use interaction.

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SIGNIFICANCE STATEMENT

The interaction of uses is an important tool to capture potentially threatened woody plants. However, it has been little explored in studies on biodiversity conservation. Our systematic review provides a compilation of ethnobiological and nutritional information on versatile food woody plants for the main timber uses, uses considered to be the most destructive to the structure of plant populations. We indicate food species native to Brazil that are strategic for food and nutritional security, due to their high nutritional potential and, at the same time, strategic for conservation, due to the probable risk of loss of their natural populations by logging. We discuss possible biocultural conservation strategies for these species. We also make recommendations for future studies on identified gaps in both ethnobiological and nutritional studies.

INTRODUCTION

In various parts of the world, studies have underscored the importance of wild food plants for the food and nutrition security of local populations, particularly during periods of food shortage (do Nascimento et al., 2012, 2011; Medeiros Jacob et al., 2020; Medeiros et al., 2021; Shackleton et al., 2015; Shackleton and Shackleton, 2004). Wild plants can play an important role in a healthy diet as alternative sources of minerals, vitamins, and antioxidants (Bacchetta et al., 2016; Jacob et al., 2022; Rico et al., 2016), as well as macronutrients such as carbohydrates, proteins, and lipids (Medeiros Jacob et al., 2020). Consumption of wild food plants has been recommended as part of global strategies to manage malnutrition (Hunter et al., 2019) diversify the human diet (Baldermann et al., 2016), improve food systems, and generate income for small-scale farmers and extractivists (Delang, 2014).

The importance of wild plants extends well beyond socioeconomic and nutritional factors (Medeiros Jacob et al., 2020). From a conservation perspective, studies have argued that people who rely on utilitarian and/or economic returns from forests are less likely to carry out activities that generate changes in land use in forest areas. This concept became known as the "conservation by commercialization hypothesis"(Evans, 1993; Lowore, 2020). It is also noteworthy that the extraction of edible parts of plants is, in most cases, less harmful than timber extraction, being conducive to the application of sustainable management and use strategies. However, despite the great potential of wild food plants for sustainable management, many of these species have multiple applications, including timber extraction, which is a major cause of decline among plant populations (Bruschi et al., 2014; Ros-Tonen, 2000; Stanley et al., 2012). Timber uses include fuel, construction, and technological applications (Ramos et al. 2010).

Several plants found in forests and other natural ecosystems can be used both as food and timber. Such species need to be identified and their food–wood use interactions understood to guide the development of conservation actions. Populations of species with high potential to improve food and nutrition security may be threatened by more destructive uses than food extraction. This situation is particularly worrisome for woody species that combine multiple timber uses (versatile species), as they may be facing greater use pressure. In Brazil, several studies described woody species with nutritional potential (do Nascimento et al., 2012, 2011; Medeiros Jacob et al., 2020; Nunes et al., 2012). However, most studies have failed to analyze the intersection between nutritional potential and the extent to which plant populations are threatened by uses other than human consumption. Understanding the overlap of uses of woody plants is important because conservation strategies encompassing different uses of plant resources can greatly contribute to food and nutrition security.

Species extinction represents an irreversible loss of biodiversity and cultural heritage. To avoid this problem, it is essential to develop strategies from a biocultural conservation perspective, that is, seeking to combine environmental conservation actions with knowledge on the use of natural resources to reduce the loss of biological and cultural diversity (Gavin et al., 2015). Preserving the widespread use of wild food resources might be strategic because wild plants are found in many local communities that still face challenges related to hunger, food availability, diet diversification, and climatic events impacting crop production (do Nascimento et al., 2012, 2011; Medeiros Jacob et al., 2020).

On the one hand, timber extraction tends to be harmful to plant populations, which explains its use as a threat indicator. On the other hand, it is important to emphasize that (i) timber extraction can be carried out sustainably, as has been proposed in different socioecological contexts (Bahru et al., 2021; Cavalcanti et al., 2015; Lucena et al., 2007; Tabuti et al., 2011), and (ii), in some cases, food extraction can be more damaging to plant communities than timber extraction, depending on forest management intensity. A prominent example is açaí (Euterpe oleracea Mart.), whose management has led to the simplification of estuarine communities in the Amazon Forest (Freitas et al., 2021). In this study, we approach the topic with awareness of possible contrasting effects. Nevertheless, it is understood that woody species with multiple timber uses may be exposed to greater use pressure and, consequently, higher management intensity.

In this systematic review, we aimed to identify priority species for biocultural conservation that are, at the same time, strategic for the maintenance of food and nutrition security (in terms of micro- and macronutrient composition) and potentially threatened by multiple timber uses. For this, we identified woody species native to Brazil that are used by local populations for food and timber purposes and compiled nutritional information available in the scientific literature to answer the following questions: (i) Which woody food species have high versatility as timber? and (ii) Which food and timber species have high potential to contribute to food and nutrition security?

This study presents the results of two systematic reviews. The first, of an ethnobiological nature, summarizes information on wild plants with overlapping applications as food and timber, and the second, of a nutritional nature, compiles information on the chemical composition of these species.

MATERIAL

Ethnobiological systematic review

This systematic review was conducted based on the PRISMA guidelines (see Additional File 1). Figure 1 shows a flowchart of the research steps.

Eligibility criteria

Studies were selected according to the following eligibility criteria: (i) articles of an ethnobotanical nature, (ii) original studies, and (iii) studies assessing food and/or timber plants native to Brazil. Duplicates, articles focused on herbaceous plants only, studies not indexed in major databases, and review studies were excluded. Priority was given to studies with complete floras. Studies assessing plants from only one botanical family or only a few species (<5) were excluded.

Information sources

Searches were carried out between January and February 2022 in three databases: Web of Science, Scopus, and SciELO. The first two databases were chosen because they contain the largest number of articles published in international journals and achieved excellent performance in systematic reviews (Bramer et al., 2017). SciELO was included to reach a greater number of studies published in Brazilian journals. Additional articles were identified by screening the reference list of articles identified from database searches.

Search strategy

Database searches were performed on two occasions, hereafter referred to as B1 and B2. An additional search was performed via other sources (B3). After the initial search (B1), a second search (B2) was performed to expand the retrieval of articles not identified through the initial keywords. The reference list of all articles selected in B1 was screened for potentially relevant titles, and these newly identified articles were examined. We recorded and identified the most frequent keywords used in these articles, including keywords that had not been used in B1, in order to conduct a new cycle of searches (B2) in the three databases. A third search (B3) was performed through other sources, in which articles retrieved in B2 were consulted to identify new keywords and then submitted to the selection processes described in the next section.

The same search terms were used for the three databases, with the inclusion of Portuguese keywords for searches in the SciELO database. Search efforts were directed to article titles, abstracts, and keywords by using the different fields available in each database, as follows: topic (Web of Science); title, abstract, and keywords (Scopus); and all indexes (SciELO). The search strategies used in each database are available in Additional File 2.

Study selection

Search records were saved in RIS format and imported into the Mendeley reference manager, which automatically identifies and deletes duplicates. After that, references were exported to an Excel spreadsheet. In Excel, we were able to identify and manually delete some duplicates that had not been identified by Mendeley's automatic check, possibly because of errors in the references or titles written in different languages.

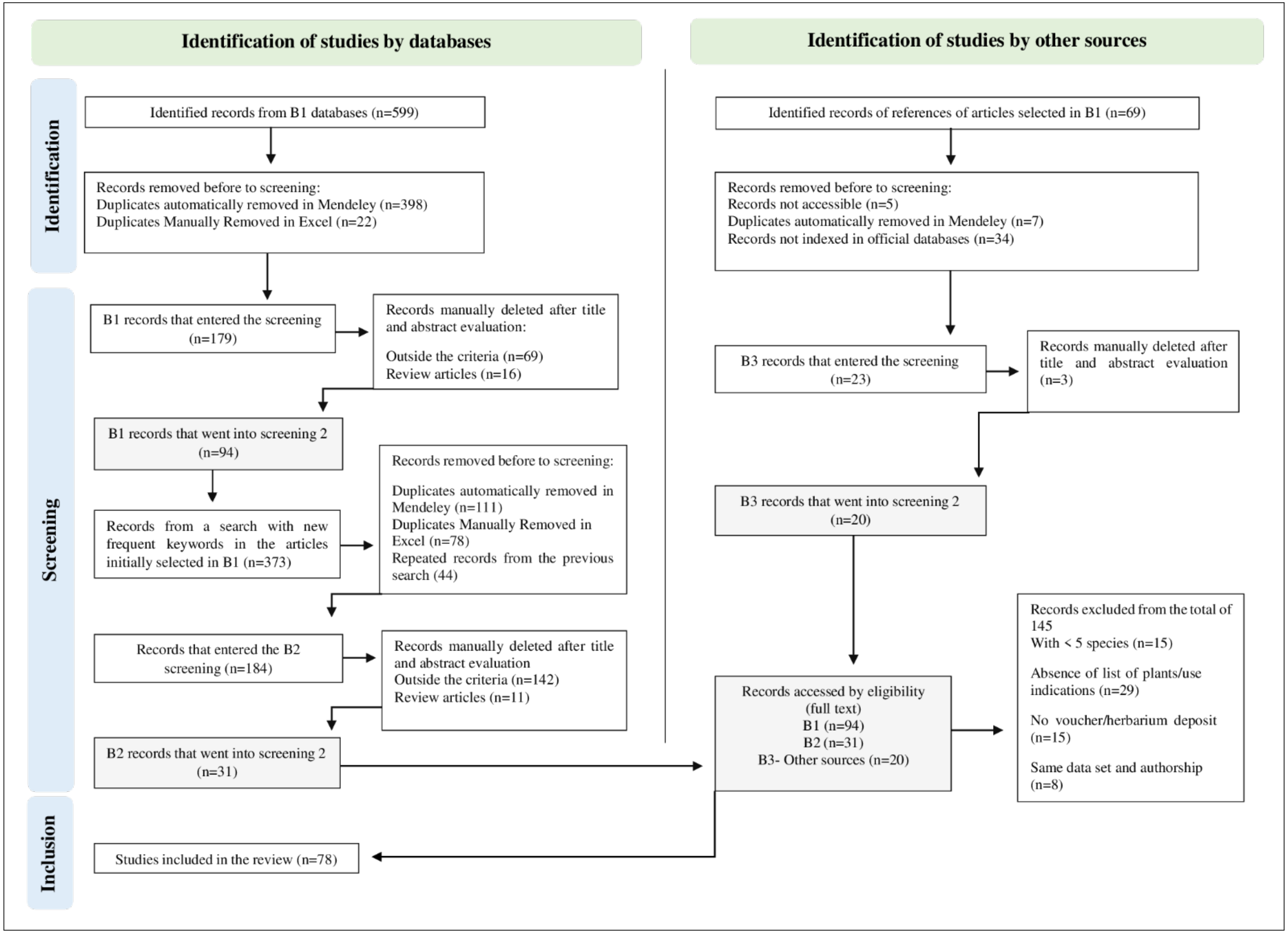

Figura 1. Flowchart with systematic review search and screening steps

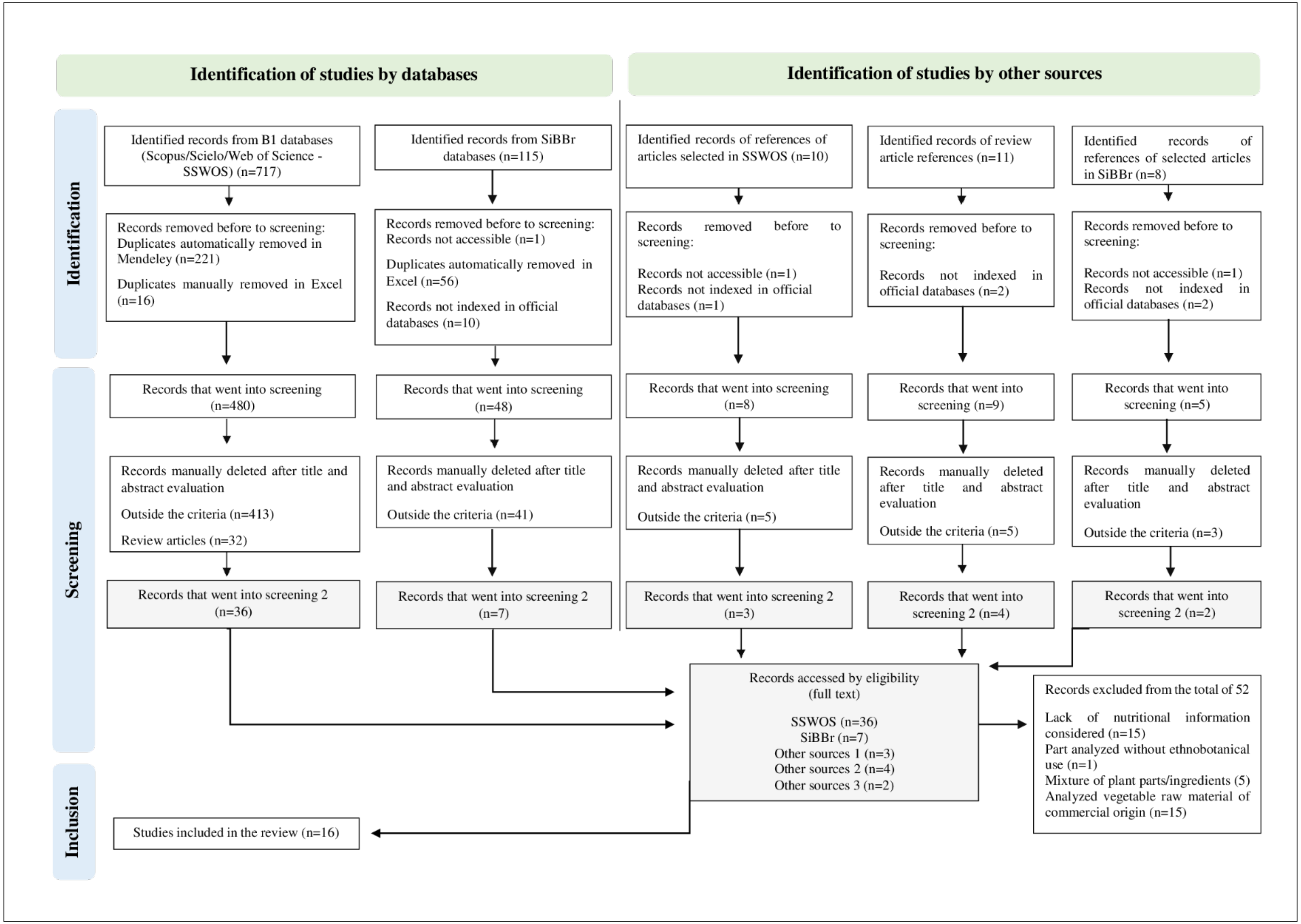

Figura 2. Flowchart with search and screening stages of the systematic review on nutritional aspects.

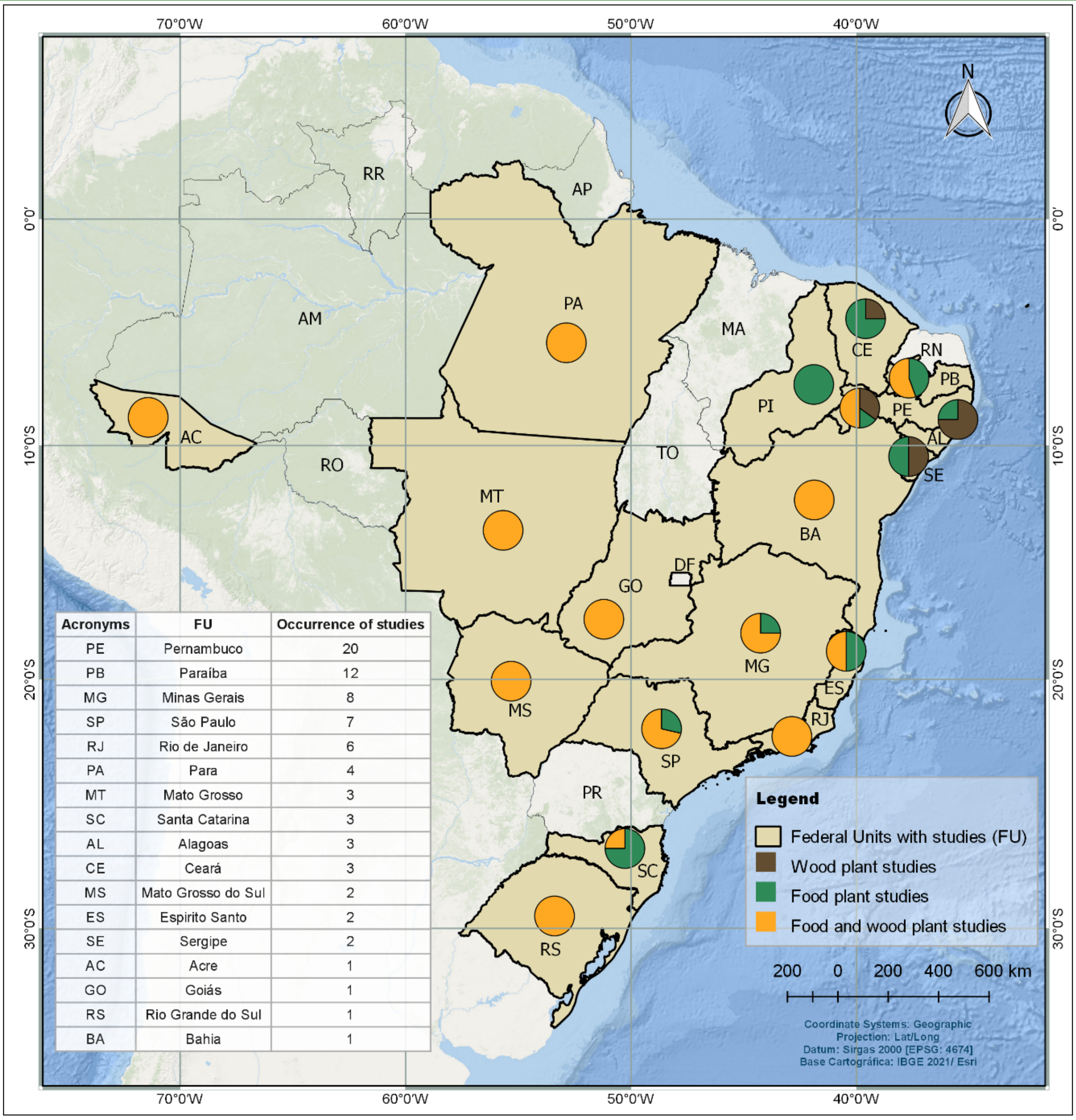

Figura 3. Distribution of studies on food and/or timber plants extracted in this systematic review. Note that 80 studies distributed throughout Brazil are expressed (two more than the number mentioned in the text - 78). This occurred because two studies were carried out in areas of two different states (Pernambuco and Paraíba). Elaborated by Klebson da Silva

The first author (RAC) selected articles individually according to previously mentioned eligibility criteria. First, titles and abstracts were screened, and those that did not meet the eligibility criteria or had already been retrieved in previous searches (B1 or B2) were excluded. In case of uncertainty regarding eligibility, another author was consulted (PMM). In the next step, potentially eligible texts were read in full, and once again analyzed according to eligibility criteria, that is, whether they presented a list of plants with indications of timber and/or food uses, analyzed more than 5 species, and did not have authors in common analyzing the same dataset. For B3 articles, as an additional quality filter before these procedures, we checked if the journals were indexed in official databases (SciELO or Scopus).

Data extraction

Data were extracted from selected articles to an Excel spreadsheet. The first author (RAC) was responsible for this procedure. The following information was collected: (a) article data (authors, year of publication, and journal), (b) plant species (without authority), (c) timber and/or food uses, and (d) use categories (food, fuel, construction, and technology).

Study quality was assessed based on the identification of botanical materials, including only articles that reported having deposited a voucher specimen in herbaria and/or indicated the voucher number in tables. This procedure was undertaken because poor identification or absence of records in herbaria could lead to the inclusion of information mistakenly linked to certain species (Medeiros et al., 2014). Although other ethnobiological studies used interviewees' samples as a criterion for risk of bias (De Medeiros et al., 2013), we chose to not apply this method, given that, for our approach, the fact that a study did not use a representative sample does not make it unfeasible to compile information on useful plants. Our approach, therefore, integrated different findings and was not aimed at comparing different studies.

Synthesis of results

Only angiosperms classified as food and/or timber were included in the species survey. Scientific nomenclature, habits, origin, botanical families, and identifiers were obtained using the flora package of R software, which is based on information from the Flora and Funga do Brasil website (Jardim Botânico do Rio de Janeiro, 2022). All taxa were updated to currently accepted nomenclature at the species level. Taxa identified only at the genus or family level were excluded, and taxa with subspecies or variety information are presented only at the species level.

For cases in which the flora package returned no result for the species, we manually consulted Flora and Funga do Brasil and World Flora Online (WFO, 2022). This review included only plants classified as native and woody (i.e., plants classified as "shrub"and/or "arboreal"in the "life form"field). Thus, our research does not cover the entire universe of wild food plants, being limited to native woody plants, which are the species of interest for conservation strategies at the food–wood interface.

Timber uses were classified according to a previous study (Ramos et al. 2010). When studies categorized or specified the uses of timber species, but such a classification merged fuel, construction, or technological applications under a different denomination (e.g., handcraft), we reclassified the use category in the spreadsheet under a new column labeled "Updated category."Species grouped together in the manufacture/handicraft categories that did not contain these specifications were excluded. This procedure did not lead to the exclusion of entire studies.

Species of high importance for biocultural conservation

Food species included in the four timber use categories (food, technology, construction, and fuel), referred to herein as versatile species, were considered of high importance from a biocultural conservation perspective.

Nutritional systematic review

The nutritional systematic review also followed PRISMA guidelines (see Additional File 3). It included only species considered versatile in the ethnobiological systematic review. A flowchart illustrating the steps in the nutritional systematic review is presented in Figure 2.

Eligibility criteria

Original articles focused on human food plants and assessing the nutritional composition of the selected plant species were screened by reading the title and abstract.

Information sources

A review of the scientific literature was conducted in the same three databases used in the previous review (Web of Science, Scopus, and SciELO) in addition to a specific database for nutritional composition information (Brazilian Biodiversity Information System, SiBBr) (SiBBr, 2022).

Search strategy

Search strings were constructed by combining the currently accepted scientific name of each species (without the authority) + nutritional. For species whose scientific names were recently modified or whose alternative nomenclatures, despite not being currently accepted, were or still are widely used in studies, alternative terms were included in the search (see Additional File 4).

The word "nutricional"was used in the SciELO database to search for articles written in Portuguese. In the SiBBr database, we used only the scientific name of species. All database searches were carried out between August and September 2022.

All procedures performed in Mendeley and Excel for the ethnobiological systematic review were also used in the nutritional systematic review. To identify additional studies from other sources, we screened the reference list of review articles directly related to the nutritional composition of the species of interest. We checked, moreover, the reference list of articles retrieved from the four databases and screened the keywords of these studies to enrich our search strategy. However, the most frequent keywords were very similar to those already in use, precluding the need for new searches.

Study selection

Duplicates, articles not indexed in official databases, and review papers were excluded. Articles analyzing mixtures of ingredients, enriched products, or quality parameters during food storage and processing were also excluded.

Data extraction

The following information was extracted from selected studies: (a) article data (authors, year of publication, and journal), (b) species names (without the authority), (c) part of the plant analyzed, (d) type of preparation, (e) ecosystem, (f) place of collection, (g) macronutrient composition (proteins, carbohydrates, and lipids), and (h) micronutrient composition (minerals and vitamins). At first, we chose to include the following micronutrients: calcium (Ca), potassium (K), phosphorus (P), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), molybdenum (Mo), chromium (Cr), selenium (Se), sulfur (S), cobalt (Co), and boron (B). However, the nutritional tables presented in the results include only the following data: available macronutrients (proteins, carbohydrates, and lipids), total energy value, and mineral contents reported in at least two articles. Thus, the tables include information on the macrominerals Ca, K, P, Mg, and Na and the microminerals Fe, Zn, Cu, and Mn. Macrominerals are defined as minerals for which the recommended daily intake is greater than 100 mg. For microminerals, the recommended daily intake is less than 100 mg (Almeida et al., 2009). Information on carbohydrates was extracted from selected articles by searching for the term "carbohydrate,"including different denominations, such as "total carbohydrates,available carbohydrates,"and "calculated carbohydrates."

Given the diversity of information found in some articles, we adopted criteria for the recording of nutritional information. For example, a study on uvaia (*Eugenia pyriformis* Cambess.) analyzed several accessions of the species. We opted to include data on the most common accession, as it is the most widely known. Another situation occurred when extracting data from a study on juá (*Ziziphus joazeiro* Mart.), which analyzed specimens collected in different regions of the country. In this case, we recorded information on the sample that had the highest values in all nutrient categories.

For the generation of nutritional tables, when more than one study analyzed the same plant species, food part, and type of preparation, we selected only one study for data extraction, whereas when studies analyzed the same species but different food parts or types of preparations, we included data from all studies. When there was an overlap between nutritional information, whether of macro- or micronutrients, plant species, or parts, we prioritized studies analyzing raw materials collected in Brazil. In case of information overlap between Brazilian studies, we selected the most recent publication.

The first author (RAC) participated in all stages of the nutritional systematic review, together with two collaborators (RZP) and (AJRCS), under the supervision of PMM.

RESULTS

Ethnobiological systematic review: General aspects

A total of 145 full papers were assessed for eligibility. Of this total, 78 were included in the ethnobiological systematic review (see Figure 1) after the exclusion of (i) publications analyzing less than five species, (ii) articles without indication of timber/food uses, (iii) articles that did not mention the inclusion of voucher specimens in herbaria, and (iv) studies that used the same dataset and had at least one author in common.

Most studies included in the review are of a descriptive nature and can be classified into three groups: studies on food plants (n =18), studies on timber plants (n = 15), and studies on plants with multiple uses (n = 45). The selected studies were conducted between 1992 and 2021 in all regions of the country, especially in the Northeast and Southeast. A map of Brazil showing the occurrence frequency of studies on plant groups included in this review is presented in Figure 3.

Most studies are concentrated in the Caatinga (n = 27) and Atlantic Forest (n = 27) biomes. The ecosystems with the lowest number of studies were Cerrado (4) and Pantanal (2). Additional information is presented in Table 1.

Versatile woody food species used as timber

A total of 635 native woody angiosperms were recorded, of which 167 are used exclusively for food, 328 exclusively as timber, and 140 for both purposes. Of the woody food species used in all timber applications (fuel, construction, and technology), 42 are native to Brazil. However, given that many studies did not indicate the specific type of timber application, it is

Tabela 1. Regions and ecosystems in Brazil where the studies were carried out.

Brazilian regions	Number of studies
Northeast	40
Southeast	22
Midwest	6
North	5
South	4
South/Southeast	1
Ecosystems	**Number of studies**
Caatinga	27
Atlantic forest	27
Cerrado	4
Pantanal	2
Amazon	5
Atlantic Forest and Cerrado	2
Pantanal and Cerrado	1
Various[a]	3
Missing information	7

[a] When there are more than two informed ecosystems

possible that the number of versatile species is much higher.

We observed that half of the versatile species occur in the Caatinga, supported by the fact that most studies specifying the type of timber use were carried out in this biome. The most represented botanical families in number of species were Anacardiaceae (n = 7), Fabaceae (n = 6), and Myrtaceae (n = 4). Other six families were represented by two species each, namely Lauraceae, Euphorbiaceae, Capparaceae, Celastraceae, Burseraceae, and Bignoniaceae. The major genera, represented by two species each, were Spondias, Handroanthus, Monteverdia, Ocotea, and Eugenia (Table 2).

The plant parts most frequently mentioned were fruits (n = 26), flowers (n = 4), and seeds (n = 4). Leaf, root, and pseudofruit/floral peduncle were cited twice each, and exudate and resin were cited once. The parts of interest of six species were not specified in any study.

Tabela 2. Woody food plants considered versatile because they are used in the three categories of wood uses (fuel, construction and technology). Data from the systematic review of Brazilian ethnobiological studies

Family	Scientific name
Anacardiaceae	*Anacardium occidentale* L.
	Astronium urundeuva (M.Allemão) Engl.
	Schinus terebinthifolia Raddi
	Spondias mombin L.
	Spondias tuberosa Arruda
	Tapirira guianensis Aubl.
	Thyrsodium spruceanum Benth.
Araliaceae	*Didymopanax morototoni* (Aubl.) Decne. & Planch.
Bignoniaceae	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos
	Handroanthus serratifolius (Vahl) S.Grose
Burseraceae	*Commiphora leptophloeos* (Mart.) J.B.Gillett
	Protium heptaphyllum (Aubl.) Marchand
Cactaceae	*Pilosocereus pachycladus* F.Ritter
Capparaceae	*Cynophalla flexuosa* (L.) J.Presl
	Neocalyptrocalyx longifolium (Mart.) Cornejo & Iltis
Celastraceae	*Monteverdia obtusifolia* (Mart.) Biral
	Monteverdia rigida (Mart.) Biral
Combretaceae	*Combretum leprosum* Mart.
Euphorbiaceae	*Croton heliotropiifolius* Kunth
	Manihot dichotoma Ule
Fabaceae	*Amburana cearensis* (Allemão) A.C.Sm.
	Anadenanthera colubrina (Vell.) Brenan
	Bauhinia cheilantha (Bong.) Steud.
	Copaifera langsdorffii Desf.
	Inga thibaudiana DC.
	Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz
Lauraceae	*Ocotea glomerata* (Nees) Mez
	Ocotea odorifera (Vell.) Rohwer
Lecythidaceae	*Eschweilera ovata* (Cambess.) Mart. ex Miers
Malpighiaceae	*Byrsonima sericea* DC.
Moraceae	*Brosimum guianense* (Aubl.) Huber
Myrtaceae	*Eugenia pyriformis* Cambess.
	Eugenia uniflora L.
	Myrcia splendens (Sw.) DC.
	Psidium guineense Sw.
Rhamnaceae	*Ziziphus joazeiro* (Mart.)
Rubiaceae	*Genipa americana* L.
Sapindaceae	*Talisia esculenta* (Cambess.) Radlk.
Sapotaceae	*Sideroxylon obtusifolium* (Roem. & Schult.) T.D.Penn.
Simaroubaceae	*Simarouba amara* Aubl.
Urticaceae	*Cecropia pachystachya* Trécul
Ximeniaceae	*Ximenia americana* L.

Nutritional systematic review: General aspects

After the first stage of screening, 52 articles were retained and read in full (see Figure 2). Of these, 36 articles were excluded for the following reasons: (i) raw material of commercial origin (in these studies, pulps/fruits were obtained commercially and information on place of origin or possible mixtures with other materials or parts, such as nectar, peel + pulp, or mesocarp + exocarp, pericarp, was not provided), (ii) absence of nutritional information (e.g., studies on bioactive compounds), (iii) plant parts with no ethnobotanical uses identified in our previous review, and (iv) plant parts and ingredients mixed and/or analyzed in combination (e.g., pulp and peel, sweetened nectar). Therefore, 16 articles were included for compilation of nutritional data. These studies were published between 1986 and 2020.

Of the 17 studies included in this review, only 4 concerned plant material collected in countries other than Brazil (Nigeria and India). The plant species with the most nutritional studies were *Anacardium occidentale* L. (n = 5), *Spondias mombin* L. (n = 4), and *Pilosocereus pachycladus* F.Ritter (n = 2). Five species were addressed in a single study, namely *Genipa americana* L., *Bauhinia cheilantha* (Bong.) Steud., *E. pyriformis* Cambess., *Manihot dichotoma* Ule, and *Z. joazeiro* (Mart.).

After application of eligibility criteria, 11 articles were selected to generate the nutritional tables, 10 of which concerned material collected in Brazil. Four of these studies provided information on both macro- and micronutrients. The nutrients analyzed in nutritional tables and the number of species investigated are described in Table 3. The nutritional tables (Tables 4 and 5) contain information on eight plant species. Two studies analyzed different plant parts of *A. occidentale* (nut and pseudofruit) and *P. pachycladus* (cladode and fruit). The main plant tissue analyzed was the fruit (n = 5). Other parts included cladode, root, seed, nut, and fruit/pseudofruit (floral peduncle of cashew).

Macro- and micronutrient contents in versatile wild food plants used as timber

A. occidentale

The nut and fruit/pseudofruit of the species were analyzed, with more than one type of preparation reported. The analyzed studies provided information on the macronutrient composition of the plant. The highest macronutrient content was found in cashew nut. The major macronutrients were lipids in both roasted (47.79 g) and raw (47.4 g) cashew nuts. These values are similar to the lipid content of peanut (Arachis hypogaea L.), as reported by (Ayoola, P. B, Adeyeye, 2010). The lipid content of roasted cashew nut is higher than that of roasted peanut (40.60 g).

A. occidentale nut also had the highest micromineral contents, including K (roasted, 556.16 mg; raw, 540 mg), P (roasted, 1101.04 mg; raw, 470 mg), and Mg (roasted, 277.09 mg; raw, 240 mg). Regarding microminerals, the species is rich in Zn (roasted, 4.98 mg; raw, 5.0 mg). The micronutrient contents of cashew nut are higher than those of peanut (Ayoola, P. B, Adeyeye, 2010).

B. cheilantha

The macronutrient content of different preparations of *B. cheilantha* seed flour was assessed. Protein was the major macronutrient (soaked flour, 36.0 g; raw seed flour, 35.9 g; heated seed flour, 31.5 g). The protein content of the seed flour is similar to that of peeled soybean (*Glycine max* (L.) Merr.) seed (37.8 g) (TBCA, 2022). In our review of the literature, no data were found on the micronutrient content of *B. cheilantha*.

E. pyriformis

The fruit pulp of the species is rich in carbohydrates (53.651 g), having a higher content than the fruit pulp of *Mangifera indica* L. (16.0 g), according to the Brazilian Food Composition Table (TBCA, 2022). The carbohydrate content of *E. pyriformis* fruit pulp is also higher than that of a well-known banana variety (*Musa acuminata* Colla × *Musa balbisiana* Colla), which, raw, contains 32.1 g of carbohydrates (TBCA, 2022).

E. pyriformis had the highest Ca content (341.33 mg) among all evaluated species. This micronutrient content is higher than that of raw orange (*Citrus sinensis* (L.) Osbenk., 34.6 mg) (TACO, 2011). *E. pyriformis* ranked second in P (134.00 mg) and Mg (41.00 mg) contents and third in K content (134.00 mg). Compared with *C. sinensis*, the micronutrient contents of *E. pyriformis* are high, except that of K, which is higher in orange (170 mg) (TACO, 2011).

The major microminerals in *E. pyriformis* are Fe (5.37 mg), Cu (0.58 mg), and Mg (3.05 mg). The Fe content of the species is higher than that of conventional fruits, such as plantain, orange, strawberry (*Fragaria × ananassa*), and Hass avocado (*Persea americana* L.) (Motalab et al., 2022; Rozan et al., 2021; TACO, 2011). Furthermore, the Mn content of *E. pyriformis* is higher than that of avocado pulp (0.30 mg) (Motalab et al., 2022).

Tabela 3. Nutrients and number of species contain them

Nutrient type	Number of plant species
Carbohydrates	6
Lipids	7
Proteins	8
Calcium	4
Iron	4
Zinc	2
Potassium	3
Phosphorus	4
Sodium	2
Copper	2
Magnesium	3
Manganese	2

M. dichotoma

M. dichotoma root flour has high carbohydrate content (24.2 g), although lower than that of the more common species of the same genus *Manihot esculenta* Crantz (87.9 g) (TACO, 2011). However, it is similar to raw yam (*Colocasia esculenta* L.) in terms of carbohydrate content (23.2 g) (TACO, 2011).

Although it is widely used as both fodder and human food, especially in periods of scarcity, *M. esculenta* is reported to have toxic properties (do Nascimento et al., 2012; Nunes et al., 2018). Adequate preparation is necessary before consumption to avoid poisoning, which has been reported by local peoples over the years. In our review, no data on micronutrients were found for this species.

S. mombin

The fruit does not have an expressive macronutrient content; nevertheless, it has gained relevance for its micronutrient content. The major macromineral was Na (5.551 mg), with the highest value among the analyzed species. *S. mombin* ranked second in K content (288.276 mg) and third in P (32.849 mg) and Mg (15.095 mg) contents. Compared with avocado, a reference fruit in terms of these macronutrients (K, 514.6 mg; P, 60.5 mg; Mg, 27.7 mg), S. mombin fruit has low contents (Rozan et al., 2021). However, these values are higher than those of raw *C. sinensis* fruit (TACO, 2011).

S. mombin fruit had the second-highest Cu (0.118 mg) and Mn (0.025 mg) contents, behind only *E. pyriformis*. Its Cu content is higher than that of *C. sinensis* (0.04 mg) (TACO, 2011).

G. americana

Genipap pulp ranked third in the macromineral Ca (45.82 mg) and micromineral Fe (0.80 mg). Genipap has a higher Fe content than strawberry (*Fragaria* × *ananassa*), reported as 0.41 mg by (Motalab et al., 2022), and a higher Ca content than Hass avocado pulp (*P. americana*), reported as 13.4 mg (Rozan et al., 2021). The macro- and micronutrient contents are listed in Tables 4 and 5.

Woody species with the potential to promote food and nutrition security

Of the species for which macro- and micronutrient data were available, six stood out for their nutritional value, namely *A. occidentale* (roasted and raw cashew nuts), *E. pyriformis* (fruit pulp), *S. mombin* (fruit pulp), *M. dichotoma* (root flour), *G. Americana* (fruit pulp), and *B. cheilantha* (seed flour). Although all nine versatile species have some nutritional value and are versatile in terms of timber applications, demonstrating their importance for further conservation and nutritional studies, we consider these six species as priorities for future studies. A summary of the results on woody food species used as timber identified in this systematic review is presented in Figure 4.

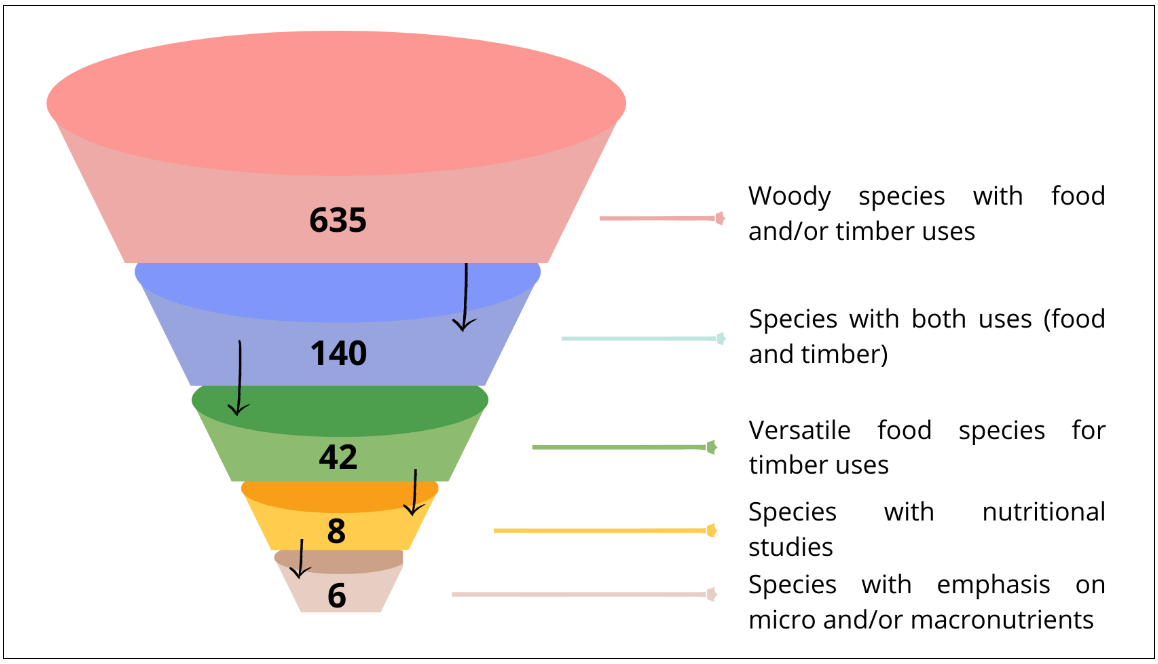

Figura 4. Number of woody food and/or timber species found during the stages of the ethnobiological and nutritional reviews. Edited in Canva (free version).

Tabela 4. Macronutrient composition of parts of versatile food woody plants for wood uses. Data from the systematic review of nutritional studies.

Species name	Analyzed part	Preparation type	Protein	Carbohydrates	Lipids	Sources
Anacardium occidentale L.	Pseudofruit (peduncle)	Pulp	1.130*	-	0.666*	Singh et al. (2019)
	Cashew nut	Ground (roasted)	22.67	19.86	47.79	Oliveira Sousa et al. (2011)
	Cashew nut	Fresh (Raw)	20.2	20.9	47.40	Rico et al. (2015)
Bauhinia cheilantha (Bong.) Steud.	Seed	Raw flour	35.9	6.2	8.7	Teixeira et al. (2013)
		Soaked flour	36.0*	7.0*	8.6*	
		Heated flour	31.5	12.8	8.6	
Eugenia pyriformis Cambess.	Fruit	Pulp	2.617	53.651	0.924	Silva et al. (2019)
Genipa americana L.	Fruit	Pulp	0.68*	-	0.35*	Figueiredo et al. (1986)
Manihot dichotoma Ule	Root	Flour	0.1*	24.2*	0.4*	Nascimento et al. (2012)
Pilosocereus pachycladus F.Ritter	Cladode	Crushed	0.25	4.75	0.53	Nascimento et al. (2011)
	Fruit	Pulp	1.15*	-	-	Souza et al. (2015)
Spondias mombin L.	Fruit	Pulp	1.06	13.9	0.62	Tiburski et al. (2011)
Ziziphus joazeiro (Mart.)	Fruit	Pulp	1.68	-	0.17	Oliveira et al. (2020)

*Nutritional values in which the unit of macronutrient composition is percentage.

Tabela 5. Composition of mineral content (mg/100g) in parts of versatile food woody plants for wood uses. Data from the systematic review of nutritional studies.

Species name	**Analyzed part**	**Preparation type**	**Ca**	**Fe**	**Zn**	**K**	**P**	**Mg**	**Cu**	**Mn**	**Na**	**Sources**
Anacardium occidentale L.	Cashew nut	Ground (roasted)	64.05*	3.89*	4.98*	556.16*	1101.04*	277.09*			3.08*	Oliveira Sousa et al. (2011)
		Fresh (Raw)	28.0	5.1	5.0	540.0	470.0	240.0	-	-	-	Rico et al. (2015)
Eugenia pyriformis Cambess.	Fruit	Pulp	341.33*	5.37*	1.03*	134.00*	134.00*	41.00*	0.58*	3.05*	-	Silva et al. (2019)
Genipa americana L.	Fruit	Pulp	45.82*	0.80*	-	-	33.50*	-	-	-	-	Figueiredo et al. (1986)
Spondias mombin L.	Fruit	Pulp	11.038*	0.327*	-	288.276*	32.849*	15.095*	0.118*	0.025*	5.551*	Tiburski et al. (2011)

*Medium values

DISCUSSION

Versatile woody food species used for fuel, construction, and technological applications

In this systematic review, we identified a significant number of native species that may be suffering from intensive use (n = 42), because they are traditionally used as food and also for timber purposes (fuel, construction, and technology) (see Table 2). These numbers might be underestimated, given that many studies did not detail the categories of timber use, hampering analysis of versatility. Studies on the harvesting patterns of timber resources have shown that there are differences in replacement time, parts of plants used, harvest volume, and the state in which the plant material is preferentially harvested (alive or dead) according to timber use (De Medeiros et al., 2012). However, it is not yet possible to identify which usage is more harmful to plant populations. Various studies indicated the potential effect of chronic anthropogenic disturbances on gradual extinction of local species and alteration of vegetation structure (Ribeiro et al., 2019, 2015). Therefore, the greater the timber versatility of a given species, the greater the chances that it is somehow affected by unsustainable management strategies.

Of the identified versatile species, at least five are characterized as preferential fuel wood in the Brazilian semiarid because of their physical properties, namely *Anadenanthera colubrina*, *B. cheilantha*, *Astronium urundeuva*, *A. occidentale*, *Z. joazeiro*, *M. dichotoma*, and *Eugenia* sp. (Bahru et al., 2021) . It is possible that these species are suffering high use pressure from local populations, given their good timber qualities.

A total of 31 of the 42 identified species are classified as least concern in the Red List of the International Union for Conservation of Nature (IUCN, 2022). Moreover, eight are not on this list, and three are considered important from a conservation point of view. *Amburana cearensis* and *Handroanthus serratifolius* are classified as endangered, with a declining population trend. *Handroanthus impetiginosus* is classified as near threatened, with a declining population. Other species, despite being classified as least concern, have records of decreasing population trends in some areas. This is the case of *A. colubrina*, *Protium heptaphyllum*, and *P. pachycladus*. *A. urundeuva* is overexploited as timber and is classified as data deficient. This category indicates that more information is needed for possible reclassification of the species and that potential threats are not excluded.

Although there was no information on the nutritional characteristics of these species, except for *P. pachycladus*, we believe that they must be included in conservation strategies. It is also necessary to quickly identify whether any of these species have strategic importance for food security, as this factor would be an additional argument for the creation of public conservation policies.

Strategic species for food and nutrition security and biocultural conservation

Of the nine species with available nutritional data, six stood out in terms of macronutrient (proteins, lipids, and carbohydrates) and/or mineral contents: *A. occidentale, E. pyriformis, S. mombin, M. dichotoma, G. americana*, and *B. cheilantha*. Some of these are well-known for their food applications, such as *A. occidentale, S. mombin*, and *G. americana*, whose pulps are sold in various regions of Brazil. Figure 5 shows photographs of fruit pulps marketed by a company in Alagoas State. In addition to occurring naturally in Brazilian ecosystems, these three species are also domestically grown and cultivated on a small/medium scale (Araújo et al., 2010; Mattietto and Matta, 2011; Rocha et al., 2015), contributing to the reduction of conservation pressures.

Species with high nutritional potential but little used as food (*E. pyriformis*, *M. dichotoma*, and *B. cheilantha*) deserve special attention in conservation strategies, because they are obtained almost entirely by extraction practices; there are few reports of their cultivation in agroforestry systems (Florentino et al., 2007; Freitas et al. 2016). For species with low food popularity, biocultural conservation strategies could include dissemination of their food potential, which could contribute to income generation and reduction of timber extraction. In fact, a study conducted in the Brazilian semiarid demonstrated that species with high medicinal potential were less used for timber purposes than would be expected considering their availability and wood quality (Silva et al., 2021). It is necessary, however, to test the hypothesis of protective effects from food use in other socioenvironmental contexts.

Additional strategies that involve the entire plant community and not only species of food interest are required, given that, if one species is protected from extraction, other timber species may be targeted compensatorily, intensifying anthropogenic pressures on the latter. Because low income in the countryside in certain regions of Brazil has been one of the greatest intensifiers of logging for domestic purposes (De Medeiros et al., 2012; Specht et al., 2015), strategies that generate income from the marketing of wild food plants could have a secondary effect on timber use.

Sustainable extraction of species with nutritional importance can be achieved by their inclusion in agroforestry systems, enhancing the supply of these products, increasing the chances of successful food–timber management, and linking agriculture and extractivism. In some regions of the country, however, small farmers are reluctant to make the transition from conventional cropping to agroforestry, especially because of uncertainties regarding the success of such systems, a possible decrease in the yield of the main crop, lack of successful models, and limited knowledge on the subject (Sagastuy and Krause, 2019). Some of the difficulties encountered by agroforestry farmers include the marketing of agroforestry products and absence of public policies (Shennan-Farpón et al., 2022). Thus, a public approach toward agroforestry production is essential to increase the cases of success and the number of small producers and extractivists involved in the practice.

The biocultural conservation strategies discussed herein should be aimed not only at the few versatile species with available nutritional studies but at all species with overlapping timber and food potentials. Four of the five versatile food species with timber applications that did not have nutritional information in the literature are classified as least concern in the IUCN Red List (IUCN, 2022), namely *Byrsonima sericea*, *Combretum leprosum*, *Monteverdia rigida*, and *Ocotea glomerata*. Although these species are currently classified in this category, our first systematic review identified that these species are used as food and timber. In other words, these species may be suffering from anthropogenic pressure with regard to timber extraction in local and regional contexts, which could compromise their populations over time, hampering their use in food systems.

Even for species with available data, it is necessary to carry out local diagnostics to identify the real use pressure on these resources, the feasibility of incorporating them into regional agroforestry systems, and the potential for expanding associated demand and production chains. Studies focused on consumer behavior can be strategic for identifying potential demands (Barbosa et al., 2021).

Recommendations for future ethnobiological studies

It is important to fill the knowledge gap on the sustainability of timber extraction of species at the food–wood interface. In addition to biological conservation, the cultural importance of these species must be investigated and preserved, given that these aspects are inseparable (Gavin et al., 2015).

Many ethnobiological studies on food plants do not identify the edible parts that are consumed or used in traditional preparations. This makes it difficult to carry out nutritional analyses focused on specific parts of the plant that are appreciated or of commercial value to local communities. This lack of information is also observed in timber research, as various studies do not indicate the type of application of timber species. Considering the heterogeneity of use dynamics among different timber categories (Walters, 2005) and the need to understand the versatility of timber species, we recommend that further studies provide more details on the timber uses of target species.

Study limitations

Given that this is a systematic review, it is important to highlight that species not contemplated here may also be versatile and, therefore, could be included in the group of keystone species. The key species identified might be biased by the research effort, which was greater in certain ecosystems of the country, such as the Caatinga. This is due to the fact that there is a higher proportion of ethnobiological studies in the Caatinga biome and that these studies provided

Figura 5. Commercial fruit pulps of the species (A) *S. mombin*, (B) *A. occidentale* and (C) *G. americana*. Edited in Canva (free version).

more information on timber uses. It is possible that there are many other priority species for conservation in other ecosystems but that have not been as widely studied as Caatinga species. The current study can be seen as a preliminary effort, which will need to be augmented with new species through further investigations.

CONCLUSION

We identified a representative number of native woody plants that have overlapping uses as food and timber. Such results underscore the need to assess sustainability and propose conservation strategies for these species to ensure the continued existence of potential resources for food and nutrition security. On the basis of ethnobiological and nutritional data available in the literature, as well as ecological profiles, we recommend that *E. pyriformis* and *B. cheilantha* be the target of ecological studies and popularization strategies because they are versatile in terms of timber uses and have high nutritional relevance.

ACKNOWLEDGMENT

We thank the collaborators André José Rubião Cavalcante da Silva (AJRCS) and Emilly Luize Guedes da Silva (ELGS) for their participation in the data collection stages of this systematic review.

FUNDING

This work was funded by the Brazilian Fund for Biodiversity – FUNBIO, by HUMANIZE and Eurofins Foundation (FUNBIO - Conserving the Future Scholarships, granted to RAC, nº 025/2022), National Council for Scientific and Technological Development (CNPq) (Scholarship doctorate to RAC, n° 141873/2020-5).

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose and have no conflicts of interest to declare that are relevant to the content of this article.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

Not applicable for this research.

CONSENSUS FOR PUBLICATION

Not applicable for this research.

OTHER INFORMATION

We declare that this review has not been registered.

SUPPLEMENTARY INFORMATION

Additional File 1: PRISMA Protocol Checklist – Ethnobiology review.
Additional File 2: Search strategies – Ethnobiology review.
Additional File 3: PRISMA Protocol Checklist – Nutritional review. Additional File 4: Search strategies – Nutritional review.

AVAILABILITY OF DATA AND MATERIALS

Datasets that support the conclusions of this article are included in the article (and its appendices). Other data referring to the list of articles of systematic reviews can be made available on request.

AUTHOR STATEMENT

RAC – Conceptualization; Investigation; Methodology, Data curation, Writing - original draft. EMCS – Organization and creation of figures; Writing - revision and editing. RRVS e ARC – Supervision; Writing - revision and editing. PMM – Conceptualization; Methodology; Writing - revision and editing. RZP – Methodology; Data curation, Writing - revision and editing.

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Received: 19 April 2022
Accepted: 10 July 2022
Published: 22 July 2023

Editor: Michelle Cristine Medeiros Jacob

Additional Files

Add File 1. PRISMA Protocol Checklist – Ethnobiology review.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	2-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	5
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	6-7
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	7, 8 and additional file 2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	8-9
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	9-10
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	8-9
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	9
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	NA
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	8
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	8-9
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	9-10
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	9-10
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	NA
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	14 and Fig.1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	14
Study characteristics	17	Cite each included study and present its characteristics.	14-16
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	NA
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	NA
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	16-18
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	NA
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	26-30
	23b	Discuss any limitations of the evidence included in the review.	26 and 30
	23c	Discuss any limitations of the review processes used.	30
	23d	Discuss implications of the results for practice, policy, and future research.	30
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	NA
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	NA

Section and Topic	Item #	Checklist item	Location where item is reported
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	31
Competing interests	26	Declare any competing interests of review authors.	32
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	32

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

*PRISMA Protocol Checklist for Ethnobiology review studies

Add File 2: Search strategies – Ethnobiology review.

Search 1 (B1)		Search 2 (B2)
Key words - Scopus, Web of Science and Scielo	Key word in Portuguese - Scielo	Key words - Scopus, Web of Science and Scielo
("edible plants" OR "food plants" OR "wild food plants" OR "non-timber forest products" OR "food uses") AND ethnob* AND Brazil	("plantas comestíveis" OR "plantas alimentícias" OR "plantas alimentícias silvestres" OR "plantas alimentares" OR "produtos florestais não madeireiros" OR "usos alimentícios") AND etnob*	("local knowledge" OR "traditional knowledge") AND ethnob* AND Brazil
("wood plants" OR "wood uses" OR "wood products" OR "wood resources" OR "wood forest products" OR "timber forest products" OR "timber resources") AND ethnob* AND Brazil	("plantas madeireiras" OR "usos madeireiros" OR "produtos madeireiros" OR "recursos madeireiros" OR "produtos florestais madeireiros") AND etnob*	Key words in Portuguese - Scielo
"useful plants" AND ethnob* AND Brazil	“plantas úteis” AND etnob*	("conhecimento local" OR "conhecimento tradicional") AND etnob*
("woody plants" OR "woody species" OR "woody forest resources") AND ethnob* AND Brazil	("plantas lenhosas" OR "espécies lenhosas" OR "recursos florestais lenhosos") AND etnob*	
"multipurpose plants" AND ethnob* AND Brazil	("plantas multiuso" OR "plantas de múltiplos usos") AND etnob*	
"wild food plants" AND ethnob* AND Brazil	"plantas alimentícias silvestres" AND etnob*	
"food plants" AND ethnob* AND Brazil	"plantas alimentícias" AND etnob*	
"edible plants" AND ethnob* AND Brazil	"plantas alimentares" AND etnob*	
"non-timber forest products" AND ethnob* AND Brazil	"plantas comestíveis" AND etnob*	
"food uses" AND ethnob* AND Brazil	"produtos florestais não madeireiros" AND etnob*	
("wood plants" OR "wood species") AND ethnob* AND Brazil	("plantas madeireiras" OR "espécies madeireiras") AND etnob*	
"wood uses" AND ethnob* AND Brazil	"usos madeireiros" AND etnob*	
"wood products" AND ethnob* AND Brazil	"recursos madeireiros" AND etnob*	
("wood resources" OR "timber resources") AND ethnob* AND Brazil	"produtos madeireiros" AND etnob*	
"wood forest products" AND ethnob* AND Brazil	"produtos florestais madeireiros" AND etnob*	
"timber forest products" AND ethnob* AND Brazil NOT "non-timber"	lenha AND etnob*	
("fuelwood species" OR "fuelwood plants" OR "firewood use" OR firewood OR fuelwood) AND ethnob* AND Brazil	"uso combustível" AND etnob*	
("fuel use" OR "woodfuel") AND ethnob* AND Brazil	("carvão vegetal" OR carvão) AND etnob*	
(charcoal OR coal) AND ethnob* AND Brazil	"categoria tecnologia" AND etnob*	
"construction category" AND ethnob* AND Brazil	"categoria construção" AND etnob*	
"fuelwood category" AND ethnob* AND Brazil	"categoria combustível" AND etnob*	
"technology category" AND ethnob* AND Brazil	cercas AND etnob*	
fence AND ethnob* AND Brazil		

Add File 3. PRISMA Protocol Checklist – Nutritional review.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	2-4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	10
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	12
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Fig 2 and page 12
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	12-13
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	13-14
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	18-19
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	18-19
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	NA
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	NA
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	18-19
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	12
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	12
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	NA
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	NA

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	NA
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	NA
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	NA
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	18 and Fig.3
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	18
Study characteristics	17	Cite each included study and present its characteristics.	18-19
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	NA
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	NA
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	20-25
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	NA
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	NA
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	NA
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	NA
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	NA
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	26-30
	23b	Discuss any limitations of the evidence included in the review.	26 and 30
	23c	Discuss any limitations of the review processes used.	30
	23d	Discuss implications of the results for practice, policy, and future research.	30
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	NA
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	NA
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	31
Competing interests	26	Declare any competing interests of review authors.	32
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	32

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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* PRISMA protocol checklist for the systematic review of nutritional studies

Add File 4. Search strategies – Nutritional review.

Scopus, Web of science and Scielo (English)	**Scielo (Portuguese)**	**SiBBr**	
"*Amburana cearensis*" AND nutritional	"*Amburana cearensis*" AND nutricional	*Amburana cearensis*	
"*Anacardium occidentale*" AND nutritional	"*Anacardium occidentale*" AND nutricional	*Anacardium occidentale*	
"*Anadenanthera colubrina*" AND nutritional	"*Anadenanthera colubrina*" AND nutricional	*Anadenanthera colubrina*	
("*Astronium urundeuva*"OR "*Myracrodruon urundeuva*") AND nutritional	("*Astronium urundeuva*"OR "*Myracrodruon urundeuva*") AND nutricional	*Astronium urundeuva*	*Myracrodruon urundeuva*
"*Bauhinia cheilantha*" AND nutritional	"*Bauhinia cheilantha*" AND nutricional	*Bauhinia cheilantha*	
"*Brosimum guianense*" AND nutritional	"*Brosimum guianense*" AND nutricional	*Brosimum guianense*	
"Byrsonima sericea" AND nutritional	"*Byrsonima sericea*" AND nutricional	*Byrsonima sericea*	
"*Cecropia pachystachya* AND nutritional	"*Cecropia pachystachya* AND nutricional	*Cecropia pachystachya*	
"*Combretum leprosum*" AND nutritional	"*Combretum leprosum*" AND nutricional	*Combretum leprosum*	
"*Commiphora leptophloeos*" AND nutritional	"*Commiphora leptophloeos*" AND nutricional	*Commiphora leptophloeos*	
"*Copaifera langsdorffii*" AND nutritional	"*Copaifera langsdorffii*" AND nutricional	*Copaifera langsdorffii*	

("*Croton heliotropiifolius*"OR "*Croton rhamnifolius*") AND nutritional	("*Croton heliotropiifolius*"OR "*Croton rhamnifolius*") AND nutricional	*Croton heliotropiifolius*	*Croton rhamnifolius*
("*Cynophalla flexuosa*"OR "*Capparis flexuosa*") AND nutritional	("*Cynophalla flexuosa*"OR "*Capparis flexuosa*") AND nutricional	*Cynophalla flexuosa*	*Capparis flexuosa*
("*Didymopanax morototoni*"OR "*Schefflera morototoni*") AND nutritional	("*Didymopanax morototoni*"OR "S*chefflera morototoni*") AND nutricional	*Didymopanax morototoni*	*Schefflera morototoni*
("*Eschweilera ovata*"OR "*Eschweilera luschnathii*") AND nutritional	("*Eschweilera ovata*"OR "*Eschweilera luschnathii*") AND nutricional	*Eschweilera ovata*	*Eschweilera luschnathii*
("*Eugenia pyriformis*"OR "*Eugenia uvalha*") AND nutritional	("*Eugenia pyriformis*"OR "*Eugenia uvalha*") AND nutricional	*Eugenia pyriformis*	*Eugenia uvalha*
"*Eugenia uniflora*" AND nutritional	"*Eugenia uniflora*" AND nutricional	*Eugenia uniflora*	
"*Genipa americana*" AND nutritional	"*Genipa americana*" AND nutricional	*Genipa americana*	
("*Handroanthus impetiginosus*"OR "*Tabebuia impetiginosa*") AND nutritional	("*Handroanthus impetiginosus*"OR "*Tabebuia impetiginosa*") AND nutricional	*Handroanthus impetiginosus*	*Tabebuia impetiginosa*
("*Handroanthus serratifolius*"OR "*Tabebuia serratifolia*") AND nutritional	("*Handroanthus serratifolius*"OR "*Tabebuia serratifolia*") AND nutricional	*Handroanthus serratifolius*	*Tabebuia serratifolia*
"*Inga thibaudiana*" AND nutritional	"*Inga thibaudiana*" AND nutricional	*Inga thibaudiana*	

"*Libidibia ferrea*" AND nutritional	"*Libidibia ferrea*" AND nutricional	*Libidibia ferrea*	
"*Manihot dichotoma*" AND nutritional	"*Manihot dichotoma*" AND nutricional	*Manihot dichotoma*	
("*Monteverdia obtusifolia*"OR "*Maytenus obtusifolia*") AND nutritional	("*Monteverdia obtusifolia*"OR "*Maytenus obtusifolia*") AND nutricional	*Monteverdia obtusifolia*	*Maytenus obtusifolia*
("*Monteverdia rigida*"OR "*Maytenus rigida*") AND nutritional	("*Monteverdia rigida*"OR "*Maytenus rigida*") AND nutricional	*Monteverdia rigida*	*Maytenus rigida*
"*Myrcia splendens*" AND nutritional	"*Myrcia splendens*" AND nutricional	*Myrcia splendens*	
("*Neocalyptrocalyx longifolium*"OR "*Capparis jacobinae*") AND nutritional	("*Neocalyptrocalyx longifolium*"OR "*Capparis jacobinae*") AND nutricional	*Neocalyptrocalyx longifolium*	*Capparis jacobinae*
"*Ocotea glomerata*" AND nutritional	"*Ocotea glomerata*" AND nutricional	*Ocotea glomerata*	
"*Ocotea odorifera*" AND nutritional	"*Ocotea odorifera*" AND nutricional	*Ocotea odorifera*	
"*Pilosocereus pachycladus*" AND nutritional	"*Pilosocereus pachycladus*" AND nutricional	*Pilosocereus pachycladus*	
"*Protium heptaphyllum*" AND nutritional	"*Protium heptaphyllum*" AND nutricional	*Protium heptaphyllum*	
"*Psidium guineense*" AND nutritional	"*Psidium guineense*" AND nutricional	*Psidium guineense*	

("*Sarcomphalus joazeiro*"OR "*Ziziphus joazeiro*") AND nutritional	("*Sarcomphalus joazeiro*"OR "*Ziziphus joazeiro*") AND nutricional	*Sarcomphalus joazeiro*	*Ziziphus joazeiro*
"*Schinus terebinthifolia*" AND nutritional	"*Schinus terebinthifolia*" AND nutricional	*Schinus terebinthifolia*	
"*Sideroxylon obtusifolium*" AND nutritional	"*Sideroxylon obtusifolium*" AND nutricional	*Sideroxylon obtusifolium*	
"*Simarouba amara*" AND nutritional	"*Simarouba amara*" AND nutricional	*Simarouba amara*	
"*Spondias mombin*" AND nutritional	"*Spondias mombin*" AND nutricional	*Spondias mombin*	
"*Spondias tuberosa*" AND nutritional	"*Spondias tuberosa*" AND nutricional	*Spondias tuberosa*	
"*Talisia esculenta*" AND nutritional	"*Talisia esculenta*" AND nutricional	*Talisia esculenta*	
"*Tapirira guianensis*" AND nutritional	"*Tapirira guianensis*" AND nutricional	*Tapirira guianensis*	
"*Thyrsodium spruceanum*" AND nutritional	"*Thyrsodium spruceanum*" AND nutricional	*Thyrsodium spruceanum*	
"*Ximenia americana*" AND nutritional	"*Ximenia americana*" AND nutricional	*Ximenia americana*	